JAPANESE [JP,09-293935,A]

CLAIMS DETAILED DESCRIPTION TECHNICAL FIELD PRIOR ART EFFECT OF THE INVENTION TECHNICAL PROBLEM MEANS DESCRIPTION OF DRAWINGS DRAWINGS

[Translation done.]

CLAIMS

[Claim(s)]

[Claim 1] Thickness d1 which approaches a substrate and the aforementioned substrate, is prepared and made the principal component the gallium nitride of magnesium concentration Nbg1 cm−3 The single crystal layer of mum, it is prepared in the position whose aforementioned single crystal layer is pinched by the aforementioned substrate, and the magnesium of concentration NMgcm−3 is added -- both Thickness d2 from which aluminum composition x becomes one or less [0.02 or more] It has the semiconductor layer which makes Ga1−x Alx N of mum a principal component, and they are the aforementioned aluminum composition x, the aforementioned concentration NMg, the aforementioned concentration Nbg1, and the thickness d1. And thickness d2 Gallium-nitride system semiconductor device which has the following relations in between.

d1 -- /(1600xx) <d2 <3.6 x10−3x logN / (x+0.02) +0.02 -- here -- Ncm−3 -- NMg>Nbg1 a case -- N=NMg−Nbg1 and NMg<=Nbg1 a case -- the background level of the magnesium additive-free in N in Ga1−x Alx N -- it is .

[Claim 2] The gallium-nitride system semiconductor device according to claim 1 which is equipped with the barrier layer constituted possible [a laser oscillation] and the n type AlGaN layer prepared in the aforementioned barrier layer by approaching, is arranged so that the aforementioned barrier layer may be sandwiched by the aforementioned semiconductor layer close to the aforementioned barrier layer, and the aforementioned n type AlGaN layer, and made the thickness of the aforementioned semiconductor layer thicker than the thickness of the aforementioned n type AlGaN layer.

[Claim 3] The gallium-nitride system semiconductor device according to claim 1 which is equipped with the barrier layer constituted possible [a laser oscillation] and the n type AlGaN layer prepared in the aforementioned barrier layer by approaching, is arranged so that the aforementioned barrier layer may be sandwiched by the aforementioned semiconductor layer close to the aforementioned barrier layer, and the aforementioned n type AlGaN layer, and made aluminum composition of the aforementioned semiconductor layer higher than aluminum composition of the aforementioned n type AlGaN layer.

[Claim 4] Thickness d1 which approaches a substrate and the aforementioned substrate, is prepared and made the principal component the gallium nitride of silicon concentration Nbg2 cm−3 The single crystal layer of mum, it is prepared in the position whose aforementioned single crystal layer is pinched by the aforementioned substrate, and the silicon of concentration Nsicm−3 is added -- both Thickness d2 from which aluminum composition x becomes one or less [0.02 or more] It has the semiconductor layer which makes Ga1−x Alx N of mum a principal component, and they are the aforementioned aluminum composition x, the aforementioned concentration Nsi, the aforementioned concentration Nbg2, and the thickness d1. And thickness d2 Gallium-nitride system semiconductor device which has the following relations in between.

d1 / (1600xx) < -- d2 <3.2 x10−3 logN' / (x+0.02) +0.02 -- here -- N' (cm−3) -- Nsi>Nbg2 a case -- N'=Nsi−Nbg2 and Nsi<=Nbg2 a case -- N' -- the background level of the silicon of additive-free Ga1−x Alx N -- it is .

[Claim 5] The barrier layer constituted it is prepared in the position whose aforementioned

semiconductor layer is pinched in the aforementioned single crystal layer, and possible [exudation of light], it is prepared in the position which sandwiches the aforementioned barrier layer in the aforementioned semiconductor layer, and the magnesium of concentration NMgcm−3 is added — both It has p type clad layer to which aluminum composition x makes a principal component Ga1−x Alx N of thickness d3micrometer from which it becomes one or less [0.02 or more]. Magnesium concentration Nbg1 cm−3 of the aforementioned aluminum composition x, the aforementioned concentration NMg, and the aforementioned single crystal layer, and thickness d1 And thickness d3 Gallium-nitride system semiconductor device according to claim 4 using the aforementioned semiconductor layer as an n type clad layer while it has the following relations in between.

d1 — /(1600xx) <d3 <3.6 x10−3x logN / (x+0.02) +0.02 — here — Ncm−3 — NMg>Nbg1 a case — N=NMg−Nbg1 and NMg<=Nbg1 a case — the background level of the magnesium additive-free in N in Ga1−x Alx N — it is .

[Claim 6] Gallium-nitride system semiconductor photogenesis equipment equipped with the n-AlGaN clad layer by which Mg of three or more [1019cm −] impurity concentration other than n type impurity for being prepared so that the barrier layer constituted possible [exudation of light], p type clad layer prepared in the aforementioned barrier layer by approaching, and the aforementioned barrier layer may be approached and the aforementioned barrier layer may be inserted in the aforementioned p type clad layer, and considering as a n-type semiconductor was added.

[Claim 7] A substrate, the buffer layer grown up in contact with the aforementioned substrate, and at least one or more-layer AlGaN layer grown epitaxially on the aforementioned substrate, It has a single crystal GaN layer below the critical thickness of at least one layer which the aforementioned substrate was approached [thickness] and grew it epitaxially. the above — the gallium-nitride system semiconductor device which occupies more than the half of the sum thickness of all the epitaxial layers that total of the thickness of one or more-layer AlGaN layer grew up on the aforementioned substrate as it is few

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[Translation done.]

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[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to the gallium-nitride system semiconductor device which has a semiconductor containing nitrogen, such as GaN, AlGaN, and InGaN, and gallium-nitride system semiconductor photogenesis equipment.
[0002]
[Description of the Prior Art] In recent years, the development of the semiconductor laser of short wavelength is furthered for the purpose of the application to a high-density optical disk system etc. By this kind of laser, in order to raise recording density, it is required that oscillation wavelength is shortened. As semiconductor laser of short wavelength, the property improvement also of which of reading of a disk and writing is carried out even at possible level, and 600nm band light source by InGaAlP material is already put in practical use.
[0003] Aiming at the further enhancement in recording density, the development of blue field semiconductor laser is performed briskly. As for the semiconductor laser by the II-VI group system, the oscillation operation was already checked. however, a reliability is limited in about 100 hours and 480nm or less of wavelength is difficult to oscillate — etc. — there are many obstructions to utilization and many material-limits exist in the application to the optical disk system of the next generation etc.
[0004] On the other hand, short-wavelength-izing is possible for GaN system type semiconductor laser to 350nm or less. Moreover, also about the reliability, it is promising and the research and the development are performed [that the reliability of 10,000 hours or more is checked in Light Emitting Diode according to conditions, etc. and] briskly.
[0005] Thus, a gallium-nitride system semiconductor is an outstanding material which fulfills conditions required for the optical disk system light source of the next generation in material.
[0006] On the other hand, for semiconductor laser formation, eye ******** to a barrier layer and eye carrier ****** are indispensable, and, for that, must use AlGaN as a clad layer. In order to realize wavelength applied to the optical disk system below and over 400nm etc., at 25% or more, 0.3 micrometers or more of one side are needed in aluminum composition also for thickness with the case of a symmetrical waveguide.
[0007] However, in manufacturing the semiconductor laser which has AlGaN layer of high aluminum composition, a trouble [like / next] arises.
[0008] It pulls from the lattice constant difference of AlGaN layer, and adjoining GaN layer or the opposite substrate, and asymmetry arises. When AlGaN thickness turns into more than a critical thickness for this hauling asymmetry, a hexagonal-method-like crack will go into the front face of AlGaN layer. Here, a critical thickness says the criticality-thickness of the ** side semiconductor in the case of producing a crack, the trusion, etc. to the semiconductor layer side which serves as ** to the semiconductor layer which becomes main, when the semiconductor layer of different species is prepared. It is considered that the asymmetry generally produced from the difference in the lattice constant with the semiconductor layer which becomes main may be the cause that a crack etc. arises in the semiconductor layer side which serves as ** by such critical thickness. Therefore, a crack etc. will not be produced if the thickness of the semiconductor layer used as ** is smaller than a critical

thickness enough. Moreover, a critical thickness changes with conditions of the modality of semiconductor, combination, and others.

[0009] First of all, there is no less than 2% of a lattice constant difference by AlN and GaN. Therefore, distortion of about 0.5% exists even if in between [aluminum composition of 20 – 30%] AlGaN, GaN, and in between. Here, when only growing up the layer containing aluminum on sufficiently thick GaN layer, the lattice constant as a substratum is governed by it of GaN. Therefore, it pulls in AlGaN layer, asymmetry will be introduced, and more than a critical mass (critical thickness) cannot be constituted without a crack. It is over the critical thickness to GaN layer which specifically becomes main [thickness called 0.2–0.5 micrometers of AlGaN layer required for eye ******** of a clad layer], and a crack arises on condition that usual.

[0010] If a crack arises, it will become difficult to pass a current in the orientation of a laminating for an element, and, for this reason, element resistance will become the big thing exceeding 50 ohms. Therefore, the reliability of an element is remarkably low, even if the laser oscillation itself is difficult and it oscillates by such laser. Moreover, a residual strain shows during energization the remarkable degradation considered to be the cause.

[0011] In the above-mentioned case, the case where the gallium nitride which is one of the III–V group compound semiconductors containing nitrogen was mainly applied to laser was explained. However, a gallium nitride can be widely used for semiconductor devices, such as not only laser but other light emitting devices, an electron device, a power device, etc.

[0012] The band gap of a gallium nitride is as large as 3.4eV, and it is a transited [directly] type. Therefore, as described above, it is promising as a charge of short wavelength light-emitting-device material. Furthermore, since the gallium-nitride system material formed of alloying with an indium nitride etc. can control a band gap in the large domain, it attracts attention as a material for creating the light emitting device of until [an orange to] ultraviolet. Moreover, the application to the element for power which employed the big band gap efficiently, an elevated-temperature operation element, etc. is also basking in the limelight.

[0013] As a substrate of a gallium-nitride system thin film material, it is stable also in the high temperature for growth of a gallium-nitride system material, and, moreover, is asked for the parvus material of the lattice constant difference with a gallium-nitride system material. a front face comparatively good in an organic-metal vapor growth (the MOCVD method) — a character is acquired and the sapphire with an easy wafer acquisition of diameter the class of 2 inches is widely used as an element formation substrate

[0014] However, when grid mismatching uses silicon on sapphire about 16% between sapphire and a gallium nitride for a certain reason, a gallium nitride tends to grow in the shape of an island. Moreover, for a certain reason [the dislocation density in such a thin film], for example, in the light emitting device, luminous efficiency was low, about [1010cm –] two had high operating voltage, and it was not enough. [of the yield]

[0015] For example, that whose photogenesis wavelength is 520nm in the gallium-nitride system light emitting diode created on silicon on sapphire shows the following properties. Luminous efficiency is the conditions of 20mA of currents, an external quantum efficiency is 6% and operating voltage is 5V. Moreover, lives are the conditions of 40mA of currents, and a poor incidence rate [in resistance-welding-time 1000 hours] is 25%. Therefore, elevation of the further luminous efficiency, a reduction of operating voltage, and reinforcement are desired.

[0016] Moreover, a problem is in the heterojunction section also in formation of the transistor which is the right hand side of electronic devices, such as a power element, an elevated-temperature element, and a high-speed operation element, and it is far from practical use.

[0017] The big cause of bringing the failure in the above semiconductor devices has the large place depended on the crack often generated in the layer of N layers of Ga1-x Alx, and its near like the case of laser.

[0018] Although the grade of occurrence of a crack is small made by reducing x of N layers of Ga1-x Alxes, it is known for light emitting diode, for example that an element life will become remarkably short. For example, although the grade of occurrence of a crack is small made by

reducing x of N layers of Ga1-x Alxes in the case of a laser diode, the current density value between laser oscillations becomes very high, and the continuous oscillation in a room temperature is checked. In the case of the fast-turn-around element, if x is reduced, a bad influence, like formation of two-dimensional electron gas becomes impossible enough is known.

[0019] Thus, in the conventional gallium-nitride system semiconductor device, it is very difficult to form AlGaN layer of high aluminum composition as a clad layer etc., and element resistance becomes remarkably high. That is, in the gallium-nitride system semiconductor device, it was simultaneously unrealizable to raise to prevent the crack of N layers of Ga1-x Alxes, to lengthen the life of an element, and the operating time current characteristic. For this reason, in laser, implementation of continuous oscillation is difficult, for example.

[0020]

[Problem(s) to be Solved by the Invention] As mentioned above, when avoiding the stacking-fault problem accompanied by aluminum introduction raises the function of a semiconductor device in the gallium-nitride system semiconductor device equipped with the semiconductor containing nitrogen, such as GaN, AlGaN, and InGaN, it is indispensable, and the problem solving is demanded.

[0021] this invention aims at it having been made in consideration of such actual condition, and avoiding the stacking-fault problem accompanied by aluminum introduction, preventing occurrence of a crack, without **ing thickness of Ga1-x Alx N, making aluminum composition of AlGaN layer high, for example, offering the gallium-nitride system semiconductor device and gallium-nitride system semiconductor photogenesis equipment sufficient [eye ******** or eye carrier ******] to a barrier layer which may be carried out.

[0022]

[Means for Solving the Problem] The thickness of a limitation becomes thin as are described above, and a critical thickness exists in Ga1-x Alx N which grows up to be tops, such as silicon on sapphire, through layers, such as a gallium nitride, for grid mismatching and aluminum composition becomes high. If it is going to acquire high aluminum composition, this would correspond to becoming easy to generate a crack, and will have been considered that it may be the cause of a material physical-properties-limitation.

[0023] However, according to the result of an addition experiment of N layers [of Ga1-x Alxes which artificers carried out] magnesium, and silicon, it found out that it could suppress occurrence of a crack so that the inclination which a crack tends to generate so that x is large has many magnesium additions of a certain thing. Although this effect was looked at by silicon addition, its effect by magnesium addition was larger.

[0024] That is, AlGaN layer which doped Mg can grow thickly, without generating a crack rather than n type AlGaN of undoping or Si dope. The effect was able to show good repeatability and was able to thicken the thickness about 50% from 20% conventionally. As impurity concentration of Mg, this effect appeared clearly in 1x1019cm-3 to 2x1020cm-3. If it considers from the surface morphology of GaN and AlGaN changing when the high concentration dope of Mg is carried out although the ground of this effect is not clear, the Mg dope itself will be considered to have affected the mode of a crystal growth. Originally, if the crack has occurred below by the critical thickness usually discussed availing of the brittleness of a crystal lengthwise [by the grounds — in a hexagonal system crystal, the trusion tends to go into a growth side perpendicularly —] etc., it can be interpreted as Mg added having suppressed the crack in longitudinal direction and the type where two-dimensional growth is *************ed.

[0025] On the other hand, artificers found out that the dominant lattice constant of a layer structure became what is AlGaN layer, when carrying out total of the thickness of AlGaN layer more than the half of a full-epitaxial thickness about the configuration of the night ****** system semiconductor device grown up on substrates, such as a sapphire. Therefore, if AlGaN layer thickness is adjusted, it can be prevented that a crack etc. occurs in AlGaN layer by the stacking fault accompanied by aluminum introduction.

[0026] More specifically, each invention of this application is realized by the following

resolution meanses based on the above-mentioned discovery.
[0027] First, invention corresponding to a claim 1 is the thickness d1 which approaches a substrate and a substrate, is prepared and made the principal component the gallium nitride of magnesium concentration Nbg1 cm-3. The single crystal layer of mum, it is prepared in the position whose single crystal layer is pinched by the substrate, and the magnesium of concentration NMgcm-3 is added — both Thickness d2 from which aluminum composition x becomes one or less [0.02 or more] It has the semiconductor layer which makes Ga1-x Alx N of mum a principal component, and they are aluminum composition x, concentration NMg, the concentration Nbg1, and the thickness d1. And thickness d2 It is the gallium-nitride system semiconductor device which has the following relations in between.
[0028] d1 — /(1600xx) <d2 <3.6 x10-3x logN / (x+0.02) +0.02 — here — Ncm-3 — NMg>Nbg1 a case — N=NMg-Nbg1 and NMg<=Nbg1 a case — the background level of the magnesium additive-free in N in Ga1-x Alx N — it is .
[0029] In the gallium-nitride system semiconductor device which fulfills such conditions, occurrence of a crack can be prevented in the layer of N layers of Ga1-x Alx, and its near, without **ing thickness of Ga1-x Alx N. Therefore, when enhancement in luminous efficiency and reduction-ization of operating voltage can be attained when light emitting diode is formed by this gallium-nitride system semiconductor device, and a laser diode is formed, the reinforcement of room temperature continuous oscillation can be achieved, and further, when an electronic device is formed, the enhancement in the operating time current characteristic can be achieved.
[0030] Next, invention corresponding to a claim 2 is the gallium-nitride system semiconductor device which is equipped with the barrier layer constituted possible [a laser oscillation] and the n type AlGaN layer prepared in the barrier layer by approaching in invention corresponding to a claim 1, is arranged so that a barrier layer may be sandwiched by the semiconductor layer close to a barrier layer, and the n type AlGaN layer, and made the thickness of a semiconductor layer thicker than the thickness of an n type AlGaN layer.
[0031] In the gallium-nitride system semiconductor device of invention corresponding to a claim 2 by having prepared such a configuration Do so the same operation effect as invention corresponding to a claim 1, and also by having made the thickness of a semiconductor layer thicker than the thickness of an n type AlGaN layer The maximum use of the crack-initiation prevention effect by magnesium addition can be carried out, and eye ******** to a barrier layer and eye carrier ****** can offer more one layer of sufficient semiconductor laser by which it was carried out and the reinforcement of room temperature continuous oscillation was made.
[0032] Moreover, invention corresponding to a claim 3 is the gallium-nitride system semiconductor device which is equipped with the barrier layer constituted possible [a laser oscillation] and the n type AlGaN layer prepared in the barrier layer by approaching in invention corresponding to a claim 1, is arranged so that a barrier layer may be sandwiched by the semiconductor layer close to a barrier layer, and the n type AlGaN layer, and made aluminum composition of a semiconductor layer higher than aluminum composition of an n type AlGaN layer.
[0033] In the gallium-nitride system semiconductor device of invention corresponding to a claim 3 by having prepared such a configuration Do so the same operation effect as invention corresponding to a claim 1, and also by having made aluminum composition of a semiconductor layer higher than aluminum composition of an n type AlGaN layer The maximum use of the crack-initiation prevention effect by magnesium addition can be carried out, and eye ******** to a barrier layer and eye carrier ****** can offer more one layer of sufficient semiconductor laser by which it was carried out and the reinforcement of room temperature continuous oscillation was made.
[0034] Furthermore, invention corresponding to a claim 4 is the thickness d1 which approaches a substrate and a substrate, is prepared and made the principal component the gallium nitride of silicon concentration Nbg2 cm-3. The single crystal layer of mum, it is prepared in the position whose single crystal layer is pinched by the substrate, and the silicon

of concentration Nsicm-3 is added — both Thickness d2 from which aluminum composition x becomes one or less [0.02 or more] It has the semiconductor layer which makes Ga1-x Alx N of mum a principal component, and they are aluminum composition x, concentration Nsi, the concentration Nbg2, the thickness d1, and the thickness d2. It is the gallium-nitride system semiconductor device which has the following relations in between.
[0035] d1 / (1600xx) < — d2 <3.2 x10-3 logN' / (x+0.02) +0.02 — here — N' (cm-3) — Nsi>Nbg2 a case — N'=Nsi-Nbg2 and Nsi<=Nbg2 a case — N' — the background level of the silicon of additive-free Ga1-x Alx N — it is .
[0036] In the gallium-nitride system semiconductor device which fulfills such conditions, occurrence of a crack can be prevented in the layer of N layers of Ga1-x Alx, and its near, without **ing thickness of Ga1-x Alx N. Therefore, when enhancement in luminous efficiency and reduction-ization of operating voltage can be attained when light emitting diode is formed by this gallium-nitride system semiconductor device, and a laser diode is formed, the reinforcement of room temperature continuous oscillation can be achieved, and further, when an electronic device is formed, the enhancement in the operating time current characteristic can be achieved.
[0037] In invention corresponding to a claim 4 in invention further again corresponding to a claim 5 The barrier layer constituted it is prepared in the position whose semiconductor layer is pinched in a single crystal layer, and possible [exudation of light], it is prepared in the position which sandwiches a barrier layer in a semiconductor layer, and the magnesium of concentration NMgcm-3 is added — both Thickness d3 from which aluminum composition x becomes one or less [0.02 or more] It has p type clad layer which makes Ga1-x Alx N of mum a principal component. Magnesium concentration Nbg1 cm-3 of aluminum composition x, concentration NMg, and a single crystal layer, and thickness d1 And thickness d3 While it has the following relations in between, it is a gallium-nitride system semiconductor device using a semiconductor layer as an n type clad layer.
[0038] d1 — /(1600xx) <d3 <3.6 x10-3x logN / (x+0.02) +0.02 — here — Ncm-3 — NMg>Nbg1 a case — N=NMg-Nbg1 and NMg<=Nbg1 a case — the background level of the magnesium additive-free in N in Ga1-x Alx N — it is .
[0039] By having prepared such a configuration, in the gallium-nitride system semiconductor device of invention corresponding to a claim 5, the operation effect of invention corresponding to a claim 1 and invention corresponding to a claim 4 will be put together, and enhancement in an element property can be aimed at much more.
[0040] It is the gallium-nitride system semiconductor photogenesis equipment equipped with the n-AlGaN clad layer by which Mg of three or more [1019cm -] impurity concentration other than n type impurity for invention corresponding to a claim 6 being prepared so that the barrier layer constituted possible [exudation of light], p type clad layer prepared in the barrier layer by approaching, and a barrier layer may be approached and a barrier layer may be inserted in p type clad layer, and on the other hand considering as a n-type semiconductor was added.
[0041] By having prepared such a configuration, in the gallium-nitride system semiconductor device of invention corresponding to a claim 6, the magnesium for originally creating a p type semiconductor is added to a n-type semiconductor, and the crack depressor effect which is not fully obtained was obtained also in the n-type semiconductor by the n-type semiconductor. Therefore, the gallium-nitride system semiconductor photogenesis equipment which can fully suppress a crack initiation also in an n-AlGaN clad layer can be offered.
[0042] Next, the buffer layer into which invention corresponding to a claim 7 was grown up in contact with the substrate and the substrate, At least one or more-layer AlGaN layer grown epitaxially on the substrate, It is the gallium-nitride system semiconductor device which occupies more than the half of the sum thickness of all the epitaxial layers that were equipped with the single crystal GaN layer below the critical thickness of at least one layer which the substrate was approached [thickness] and grew it epitaxially, and total of the thickness of at least one or more-layer AlGaN layer grew up on the substrate.
[0043] By having prepared such a configuration, total of the thickness of AlGaN layer

occupies more than the half of all the thicknesss of an epitaxial layer first in the gallium-nitride system semiconductor device of invention corresponding to a claim 7.
[0044] The lattice constant which governs an epitaxial layer can be made into the thing of AlGaN layer by this, and the crack initiation in AlGaN layer by the stacking fault etc. can be prevented.
[0045] Moreover, the grid mismatching of a substrate and a gallium-nitride system semiconductor is cancelable with the buffer layer prepared in contact with the substrate. As for a buffer layer, at this time, it is more desirable that it is the ************ layer which carried out low-temperature growth.
[0046] Next, the lattice constant difference in the case of being that whose dominant lattice constant is AlGaN layer is absorbed by the single crystal GaN layer. Although the compressive strain by the lattice constant difference have arisen in the concerned GaN layer at this time, occurrence of the new trusion in the concerned GaN layer, a crack, etc. is prevented by GaN layer's being a single crystal and being below a critical thickness.
[0047] Furthermore, this single crystal GaN layer also eases the stacking fault with a substrate or a buffer layer, also improves the flat nature on the front face of a crystal, and has closed growth of good AlGaN layer, if possible.
[0048] Therefore, it can use for a gallium-nitride system semiconductor device, being able to use AlGaN layer of high aluminum composition as a clad layer, and element resistance is fully low and the manufacture technique can also offer the easy outstanding gallium-nitride system semiconductor device. Especially in semiconductor laser, there is a big effect which not only a low threshold but a reliability makes improve.
[0049] In addition, as a means to solve the technical probrem mentioned above, the following content besides the above-mentioned means is also included.
[0050] (1) The aforementioned semiconductor layer and the aforementioned n type AlGaN layer which sandwich the aforementioned barrier layer are a gallium-nitride system semiconductor device according to claim 2 which rectifies the optical asymmetry produced by the difference in both the clad layer thickness by having the light-guide layer which has the interval-band gap of the aforementioned barrier layer and the aforementioned clad layer for a clad layer at least in one side between nothing, the aforementioned barrier layer, and each clad layer, and adjusting the aforementioned light-guide layer thickness and composition, respectively.
[0051] (2) The aforementioned semiconductor layer and the aforementioned n type AlGaN layer which sandwich the aforementioned barrier layer are a gallium-nitride system semiconductor device according to claim 3 which rectifies the optical asymmetry produced by the difference in the height of aluminum composition of both the clad layer by having the light-guide layer which has the interval-band gap of the aforementioned barrier layer and the aforementioned clad layer for a clad layer at least in one side between nothing, the aforementioned barrier layer, and each clad layer, and adjusting the aforementioned light-guide layer thickness and composition, respectively.
[0052] (3) The gallium-nitride system semiconductor device [equipped with the n-AlGaN clad layer by which Mg of three or more / 1019cm - / impurity concentration other than n type impurity for being prepared so that the aforementioned barrier layer may be inserted in the barrier layer constituted possible / exudation of light / and the aforementioned semiconductor layer used as a p type clad layer, and considering as a n-type semiconductor was added] according to claim 1.
[0053] (4) the total which has the aforementioned semiconductor layer at least among the epitaxial layers containing the aforementioned semiconductor layer grown up on the aforementioned substrate — the gallium-nitride system semiconductor device according to claim 1 to which total of the thickness of AlGaN layer occupies more than the half of all the thicknesss of the aforementioned epitaxial layer
[0054] (5) It is the gallium-nitride system semiconductor device of the above-mentioned (4) publication whose aforementioned single crystal layer it has the buffer layer grown epitaxially in contact with the aforementioned substrate, and is below a critical thickness.

[0055] (6) The aforementioned barrier layer is the gallium-nitride system semiconductor device according to claim 5 by which it is constituted possible [a laser oscillation] and Mg of three or more [1019cm -] impurity concentration was added by the aforementioned n type clad layer.
[0056] (7) the total which has the aforementioned semiconductor layer at least among the epitaxial layers containing the aforementioned semiconductor layer grown up on the aforementioned substrate — the gallium-nitride system semiconductor device according to claim 4 to which total of the thickness of AlGaN layer occupies more than the half of all the thicknesss of the aforementioned epitaxial layer
[0057] (8) It is the gallium-nitride system semiconductor device of the above-mentioned (7) publication whose aforementioned single crystal layer it has the buffer layer grown up in contact with the aforementioned substrate, and is below a critical thickness.
[0058] (9) The aforementioned barrier layer is the gallium-nitride system semiconductor photogenesis equipment according to claim 6 which is constituted possible [a laser oscillation] and made the thickness of the aforementioned p type clad layer thicker than the thickness of the aforementioned n type clad layer.
[0059] (10) The aforementioned barrier layer is the gallium-nitride system semiconductor photogenesis equipment according to claim 6 which is constituted possible [a laser oscillation] and made aluminum composition of the aforementioned p type clad layer higher than aluminum composition of the aforementioned n type clad layer.
[0060] (11) the above — a barrier layer — each — clad — a layer — between — at least — one side — the above — a barrier layer — the above — clad — a layer — the interval — like — a band gap — having — a light guide — a layer — having — the above — a light guide — a layer thickness — and — composition — adjusting — things — both — clad — a layer thickness — a difference — being generated — optical — asymmetry — rectifying — the above — (— nine —) — a publication —
[0061] (12) The compound semiconductor element containing the nitrogen characterized by having at least one or more-layer AlGaN layer, and total of the thickness of this AlGaN layer occupying more than the half of all the thicknesss of the aforementioned epitaxial layer in the compound semiconductor element containing the nitrogen which has the epitaxial layer grown up on the substrate.
[0062] (13) the above — a substrate — touching — preparing — having had — a buffer — a layer — the above — a substrate — the above — AlGaN — a layer — between — being concerned — AlGaN — a layer — touching — or — the above — AlGaN — a layer — inside — preparing — having had — at least — one — a layer — criticality — a thickness — the following — a single crystal — GaN — a layer — having — the above — (— 12 —) — a publication —
[0063] (14) The compound semiconductor element containing the nitrogen of the above-mentioned (12) publication prepared on the substrate which the aforementioned epitaxial layer becomes from an oxide.
[0064] (15) The compound semiconductor element containing the nitrogen of the above-mentioned (14) publication whose aforementioned substrate is a sapphire.
[0065] (16) The compound semiconductor light emitting device which contains the nitrogen of a publication in either among above-mentioned (12) - (15) whose aluminum composition of the aforementioned AlGaN layer is 10% or more.
[0066]
[Embodiments of the Invention] Hereafter, the gestalt of operation is explained, referring to a drawing.
[0067] It exists in Ga1-x Alx N which grows through layers, such as a gallium nitride, on silicon on sapphire for grid mismatching, the thickness, i.e., the critical thickness, of the limitation that the crack initiation which corresponds in a certain composition x does not happen. The thickness of a limitation becomes thin as x of Ga1-x Alx N, i.e., aluminum composition, becomes high. If it is going to acquire high aluminum composition, this would correspond to becoming easy to generate a crack, and will have been considered that it may

be the cause of a material physical-properties-limitation.
[0068] To be sure, if this invention person's etc. experiment is also reproduced and this inclination makes thin the thickness of N layers of Ga1-x Alxes, it can be checking that occurrence of a crack decreases.
[0069] Moreover, although the inclination which a crack tends to generate was so the same that x was large when the result of an addition experiment of N layers [of Ga1-x Alxes carried out separately] magnesium and silicon was arranged, it found out that occurrence of a crack could be suppressed so that there were many magnesium additions. Although this effect was looked at by silicon addition, its effect by magnesium addition was larger.
[0070] That is, AlGaN layer which doped Mg can grow thickly, without generating a crack rather than n type AlGaN of undoping or Si dope. The effect was able to show good repeatability and was able to thicken the thickness about 50% from 20% conventionally. As impurity concentration of Mg, this effect appeared clearly in 1x1019cm-3 to 2x1020cm-3. If it considers from the surface morphology of GaN and AlGaN changing when the high concentration dope of Mg is carried out although the ground of this effect is not clear, the Mg dope itself will be considered to have affected the mode of a crystal growth. Originally, if the crack has occurred below by the critical thickness usually discussed availing of the brittleness of a crystal lengthwise [by the grounds, like in a hexagonal system crystal, the trusion tends to go into a growth side perpendicularly] etc., it can be interpreted as Mg added having suppressed the crack in longitudinal direction and the type where two-dimensional growth is ************ed.
[0071] Drawing 1 is an outline block diagram of the organic-metal vapor-growth equipment used for the crystal growth of the gestalt of operation of this invention.
[0072] In drawing 1 , in this organic-metal vapor-growth equipment, material gas is supplied from the gas inlet 302 of the growth container 301 made from a quartz, and it has become the configuration which discharges gas from the gas exhaust port 303. Moreover, the susceptor 304 made from graphite is heated by the high-frequency-heating equipment 305, and the temperature of a susceptor 304 is measured and controlled by the W thermocouple 306. A substrate 307 is directly placed on a susceptor 304, and has taken the configuration heated.
[0073] The sample which changed various composition of N layers of Ga1-x Alxes and thicknesss, and changed various additions of magnesium or silicon was created using the vapor-growth equipment of such a configuration. And the status of the crack initiation of each created sample was investigated. This result is shown in the drawing 2 and the drawing 3 .
[0074] Ga 1-x when drawing 2 adds magnesium It is drawing showing the relation between composition of N layers of Alxes and a thickness, and a crack initiation.
[0075] Ga 1-x when drawing 3 adds silicon It is drawing showing the relation between composition of N layers of Alxes and a thickness, and a crack initiation.
[0076] In each drawing, a black dot is the sample which a crack did not generate and a white round head shows the case where a crack accepts with a light microscope. The sample of various magnesium additions is intermingled by the result shown in drawing 2 , and the magnesium concentration of each sample is within the limits of 5x1018 to 1x1020 (cm-3). On the other hand, the sample of a silicon addition various in the result shown in drawing 3 is intermingled, and the silicon concentration of each sample has it within the limits of 5x1017 to 1x1019 (cm-3).
[0077] Rather than the case where magnesium or silicon will not be added if magnesium or silicon is added, although it is as having stated previously, that thickness of N layers of Ga1-x Alxes which can form membranes, without starting a crack can be thickened understands that there is a predetermined relation to each factor from drawing 2 and the drawing 3 , even when magnesium or silicon is added.
[0078] Moreover, that it is hard to generate made the crack clear so that the crack depressor effect was so large that there were many additions of magnesium or silicon and the thickness of the layer of the substratum of N layers of Ga1-x Alxes was thin, when the same experiment was conducted further and the result was arranged, although not displayed in drawing 2 and especially the drawing 3 . The layer of a substratum here is a layer which may

make N layers of Ga1−x Alxes mainly generate asymmetry to N layers not only of the layer which has touched directly but Ga1−x Alxes. Therefore, N layers of Ga1−x Alxes which observe the layer of a substratum through other comparatively thin layers here may be prepared.

[0079] It is thought that such crack depressor effects are the effect which can suppress occurrence and propagation of the trusion if an indium, silicon, etc. are added at the time of the crystal growth of the gallium arsenide which are other III−V group compound semiconductors, and a similar effect.

[0080] Moreover, this invention person etc. found out that the element addition to a substratum was also related to the crack initiation of N layers of Ga1−x Alxes.

[0081] On the other hand, it is actually clearer than the result to which that there is no most of the effect examined N layers of Ga1−x Alxes separately when creating a semiconductor device by the junction to In1−x Gax N (0<=x<=1) and it was not 0.02 or more as an aluminum composition x value of Ga1−x Alx N.

[0082] These experimental results are unified, and in order to understand which item is involved in the crack initiation how, it is necessary to evaluate the addition of magnesium or silicon, the thickness of a substratum, the magnesium of a substratum and the concentration of silicon, and the degree of influence of each aluminum composition. Moreover, in growth of N layers of Ga1−x Alxes, occurrence of a hole may accept on membrane formation according to the growth condition. Since such presence of a hole may have influence which is not desirable to the semiconductor device which should be manufactured, it also needs to examine the growth conditions which this hole does not generate. Below, the study procedure is shown about evaluation of a crack and the occurrence conditions of a hole.

[0083] Change of the thickness of GaN (GaN of a substratum is called hereafter) which grew through the nucleation layer on silicon on sapphire finds out that asymmetry of N layers of Ga1−x Alxes which grow on the concerned GaN changes. Then, the sample to which various thickness of GaN of a substratum was changed upwards, and x of N layers of Ga1−x Alxes and the thickness (growth time) were changed was grown up using the equipment shown in drawing 1 .

[0084] The limitation that N layers of Ga1−x Alxes are flatness and a mirror plane visually after sample growth, and presence of a hole does not accept by observation of the front face by scanning−electron−microscope observation, either was investigated.

[0085] When x was the N layers of the same Ga1−x Alxes, when N layers of Ga1−x Alxes were thin, presence of a hole accepted by observation of the front face by scanning−electron−microscope observation, and when x was the same, the same phenomenon was seen when GaN layer of a substratum was thin. For example, presence of such a hole works an addition impurity kind causing a precipitation there **** or as a factor in which an anomalous diffusion is started through a hole and a hole brings a degradation of an element forward. Therefore, it was judged that this hole was what must not exist as conditioning towards reinforcement.

[0086] In proportion to composition, occurrence of the above−mentioned hole became remarkable, and the above−mentioned experiment showed that the marginal thickness of occurrence of the above−mentioned hole went up but with the same ratio of the thickness with GaN of the same thickness or a substratum by lowering x, when x was large (aluminum composition is high). This experimental result is shown in drawing 4 , the drawing 5 , and the drawing 6 .

[0087] Drawing 4 is drawing showing the relation between GaAlN layer thickness, and aluminum composition and GaN layer thickness, and drawing 5 is drawing showing the relation between GaAlN layer thickness, and aluminum composition and GaN layer thickness. Moreover, drawing 6 is drawing showing the relation between GaAlN layer thickness, and aluminum composition and GaN layer thickness.

[0088] and it examines expressing with a formula the conditions which a hole does not generate. [on the basis of the experimental result of drawing 4 − view 6] That is, it found the thickness of GaN layer of a substratum that there are the following relations when, as for the conditions as which N layers of Ga1−x Alxes are flatness and a mirror plane visually, and a

hole is not regarded by observation of the front face by scanning-electron-microscope observation, either, thickness of d1 (mum) and N layers of Ga1-x Alxes is set to d2 (mum).
[0089]
d1/1600<xd2 (0.02<=x<=1) -- (1)
That is, if the thickness of N layers of Ga1-x Alxes is above to some extent, occurrence of the above-mentioned hole can be prevented. Occurrence of a hole can be lost in the orientation of a less-than sign specifically shown in (1) formula in each composition x as shown in drawing 4 - view 6 .
[0090] In magnesium addition and silicon addition, it was checked at least that this relational expression is realized, without receiving influence in the addition impurity kind or addition to GaN or Ga1-x Alx N of a substratum.
[0091] Next, occurrence of a crack and various factors are described. It is widely known that the marginal thickness which a crack does not generate is thin so that composition x is high. As a result of accumulating an experimental result, when this relation was approximated by the inverse proportion, it turns out that it can explain an experimental result very well.
[0092] Moreover, although it was as above-mentioned that occurrence of a crack can be suppressed by adding magnesium or silicon, when impurity concentration [inside / of N layers of Ga1-x Alxes in GaN of a substratum] (magnesium or silicon) of the same kind was high, it traced that this effect faded. That is, when an impurity of the same kind exists in GaN of a substratum, and Ga1-x Alx N, I understand that only the difference is effective against crack prevention, and there is. Therefore, magnesium is added in Ga1-x Alx N, and when only silicon is added by GaN of a substratum, magnesium concentration can only explain the crack prevention effect.
[0093] On the other hand, when the direction in GaN of a substratum has high impurity concentration, it turns out that it is not based on the impurity concentration in Ga1-x AlxN, composition, and a thickness, but there are no case and change of Ga1-x Alx N additive-free in the marginal thickness of the crack initiation by impurity addition.
[0094] Ga 1-x in the sample which drawing 7 added magnesium and was created It is drawing showing the relation between composition of N layers of Alxes and a thickness, and a crack initiation.
[0095] From the experimental result shown in the drawing 2 containing the sample of various magnesium additions, this drawing samples the result in the case of the magnesium concentration 5x1019 (cm-3), and adds and displays the further experimental result of this concentration. In addition, a black dot is the sample which a crack did not generate and a white round head shows the case where a crack accepts with a light microscope.
[0096] The conditions which a crack does not generate from the result of this drawing are formula-ized. Ga1-x Alx N thickness d2 to which a crack initiation does not happen by the following formulas when magnesium is added by Ga1-x Alx N Being expressed is clearer than fitting shown in this drawing. That is, when an addition impurity is magnesium, it is a relation between the magnesium concentration NMg (cm-3) in Ga1-x Alx N, and the magnesium concentration Nbg1 (cm-3) in GaN of a substratum. d2 <3.6 x10-3x logN / (xx0.02) +0.02 -- (2)
It comes out. here -- N (cm-3) -- NMg>Nbg1 a case -- N=NMg-Nbg1 and NMg<=Nbg1 a case -- the background level of the magnesium of Ga1-x Alx N (0.02<=x<=1) additive-free in N -- it is . In addition, although not illustrated especially, it is checked that the above-mentioned (2) formula is realized also by the case of each magnesium concentration in drawing 2 . Specifically, the position of the fitting line (d2 =3.6 x10-3x logN / (xx0.02) +0.02) shown all over drawing 2 according to the size of the magnesium concentration NMg in Ga1-x Alx N and the same line will shift up and down all over drawing 2 . If magnesium concentration is high, a fitting line will move up, and if magnesium concentration is low, a fitting line will move caudad.
[0097] On the other hand, drawing 8 is drawing showing the relation between the composition of N layers of Ga1-x Alxes and the thickness in the sample which added and created silicon, and a crack initiation.
[0098] From the experimental result shown in the drawing 3 containing the sample of various

silicon additions, this drawing samples the result in the case of the silicon concentration 3x1018 (cm-3), and adds and displays the further experimental result of this concentration. In addition, a black dot is the sample which a crack did not generate and a white round head shows the case where a crack accepts with a light microscope.
[0099] When the conditions which a crack does not generate from the result of this drawing are formula-ized like the above-mentioned case and an addition impurity is silicon It is a relation between the silicon concentration Nsi (cm-3) in Ga1-x Alx N, and the silicon concentration Nbg2 (cm-3) in GaN of a substratum. d2 <3.2 x10-3xlog N' / (x+0.02) +0.02 -- (3)
It comes out. here -- N' (cm-3) -- Nsi>Nbg2 a case -- N'=Nsi-Nbg2 and Nsi<=Nbg2 a case -- N' -- it is the background level of the silicon of additive-free Ga1-x Alx N (0.02<=x<=1) In addition, although not illustrated especially, it is checked that the above-mentioned (3) formula is realized also by the case of each silicon concentration in drawing 3 . Specifically, the position of the fitting line (d2 =3.2 x10-3xlog N' / (x+0.02) +0.02) shown all over drawing according to the size of the silicon concentration Nsi in Ga1-x Alx N and the same line will shift up and down all over drawing 3 . If silicon concentration is high, a fitting line will move up, and if silicon concentration is low, a fitting line will move caudad.
[0100] Thus, the relation between the thickness of N layers of Ga1-x Alxes to which occurrence of a crack happens, and the addition of the magnesium to N layers of Ga1-xAlxes and a substratum or silicon became clear.
[0101] If the above is collected, presence of a hole will not accept by observation of the front face by scanning-electron-microscope observation, either. And Ga1-x Alx N thickness d2 for realizing the gallium-nitride system semiconductor device to which occurrence of a crack does not happen A domain In magnesium addition, (1) formula and (2) formulas showed that what is necessary was just to be in the domain of the following formulas by the relation between the magnesium concentration NMg (cm-3) in Ga1-x Alx N, and the magnesium concentration Nbg1 (cm-3) in GaN of a substratum.
[0102]
d1/(1600xx) <d2 <3.6 x10-3x logN / (x+0.02) +0.02 -- (4)
here -- N (cm-3) -- NMg>Nbg1 a case -- N=NMg-Nbg1 and NMg<=Nbg1 a case -- the background level of the magnesium of Ga1-x Alx N (0.02<=x<=1) additive-free in N -- it is .
[0103] On the other hand, when an addition impurity was silicon, (1) formula and (3) formulas showed that what is necessary was just to be in the domain of the following formulas by the relation between the silicon concentration Nsi (cm-3) in Ga1-x Alx N, and the silicon concentration Nbg2 (cm-3) in GaN of a substratum.
[0104]
d1 / (1600xx) <d2 <3.2 x10-3x logN' / (x+0.02) +0.02 -- (5)
here -- N' (cm-3) -- Nsi>Nbg2 a case -- N'=Nsi-Nbg2 and Nsi<=Nbg2 a case -- N' -- the background level of the silicon of additive-free Ga1-x Alx N (0.02<=x<=1) -- it is .
[0105] In addition, having set up conditions by each above-mentioned formula using less-than-sign"<" takes a safe side so that neither a hole nor a crack may occur certainly.
[0106] Thus, according to the semiconductor device concerning the gestalt of operation of this invention, it sets to the gallium-nitride system semiconductor laminated structure containing the layer which makes Ga1-x Alx N a principal component. The thickness d2 (mum) of the Ga1-x Alx N (0.02<=x<=1) layer of magnesium addition, the magnesium concentration NMg added with composition x, and thickness d1 of the single crystal layer which makes a principal component the gallium nitride which approached the substrate most If the relation with the magnesium concentration Nbg1 (cm-3) of the single crystal layer which makes the concerned gallium nitride a principal component is filling (4) formulas, the gallium-nitride system semiconductor device to which presence of a hole is not accepted and occurrence of a crack does not happen is realizable.
[0107] Moreover, according to the semiconductor device concerning the gestalt of operation of this invention, it sets to the gallium-nitride system semiconductor laminated structure containing the layer which makes Ga1-x Alx N a principal component. The thickness d2 (mum)

of N layers of Ga1-x Alxes of silicon addition, and the silicon concentration Nsi added with composition x, Thickness d1 of the single crystal layer which makes a principal component the gallium nitride which approached the substrate most If the relation with the silicon concentration Nbg2 (cm-3) of the single crystal layer which makes the concerned gallium nitride a principal component is filling (5) formulas The gallium-nitride system semiconductor device to which presence of a hole is not accepted and occurrence of a crack does not happen is realizable.

[0108] Thus, according to the semiconductor device concerning the gestalt of operation of this invention, in the layer of N layers of Ga1-x Alxes, and near, occurrence of a crack can be suppressed also on the conditions which thickness of N layers of Ga1-x Alxes is made thin, and there is no possibility of generating a hole which is seen with an electron microscope, and a crack generates in the former. Therefore, in light emitting diode, at the enhancement in luminous efficiency, reduction-izing of operating voltage, and laser diode, the mode of a degradation is improved by leaps and bounds by the reinforcement of room temperature continuous oscillation, and the electronic device compared with the conventional element, and the enhancement in the operating time current characteristic can be aimed at. Therefore, it is enabled to realize a long lasting semiconductor device.

[0109] (Gestalt of the 1st operation) (4) formulas by which the header was carried out [above-mentioned] with the gestalt of this operation — and — or light emitting diode was produced on the conditions with which (5) formulas are filled, and the element property was investigated Light emitting diode was produced using the organic-metal vapor-growth equipment shown in drawing 1 .

[0110] Drawing 9 , the drawing 10 , and the drawing 11 are process cross sections of the light emitting diode of the gestalt of operation of the 1st of this invention.

[0111] In the vapor-growth equipment of drawing 1 , energization was started to the high-frequency-heating equipment 305, supplying hydrogen from a gas inlet 302, and the substrate 307 401 placed on the susceptor 304, i.e., the silicon on sapphire in drawing 9 , was heated, and it adjusted so that designation of a thermocouple 306 might become 1200 degrees C. Hereafter, designation of a thermocouple 306 is only called temperature. After holding at this temperature for 10 minutes, temperature was lowered to 600 degrees C, supply of trimethylgallium (it abbreviates to TMG below), a trimethylaluminum (it abbreviates to TMA below), and ammonia gas was started in the stable place, and 30nm grew the Ga0.9 aluminum0.1 N buffer layer 402. Then, supply of TMG and TMA was stopped and temperature was re-raised at 1200 degrees C.

[0112] Subsequently, supply of the silane gas diluted with hydrogen and TMG was started, and 4 micrometers of the n type GaN layers 403 of silicon addition were grown up. Then, supply of TMG and a silane was stopped, temperature was lowered to 800 degrees C, after being stabilized, TMG and TMI were supplied, and the multiplex quantum well (MQW) structure barrier layer 404 which consists of 20 pairs of well layer In0.15Ga0.85N and barrier layer In0.05Ga0.95N using the line of TMG and TMI prepared one more line was created. After stopping supply of TMI, temperature was returned to 1200 degrees C, additional supply of bis (cyclopentadienyl) magnesium (it abbreviates to Cp2 Mg below) and the TMA was carried out in the stable place, and p mold Ga0.85aluminum0.15N layer 405 [0.3-micrometer] of magnesium addition was grown up.

[0113] Then, supply of TMA was stopped and 1 micrometer of the p type GaN layers 406 of magnesium addition was grown up as it is. Then, the silane gas diluted with hydrogen was supplied and 0.05 micrometers of the n type GaN layers 407 were grown up at the same time it stopped supply of Cp2 Mg.

[0114] Then, supply of TMG and silane gas was stopped and the energization to the high-frequency-heating equipment 305 was stopped. Supply of ammonia was stopped in the place where temperature fell to 850 degrees C.

[0115] It was a mirror plane when the wafer picked out from the growth container 301 was inspected visually. Even if it observed by the differential interference microscope, the pattern of a characteristic surface state was not seen. That is, the crack was not seen all over the

wafer. Moreover, although the surface state was observed by the scanning electron microscope in the state of drawing 9 , it is flat and characteristic patterns, such as a hole, a projection, and a wave, were not seen.
[0116] It is ****** to the p type GaN layer 406 of magnesium addition of the whole surface of the wafer obtained as mentioned above by reactive ion etching.
[0117] Next, etching conditions are determined on the basis of the distance from the maximum front face checked by cross-section electron microscope observation to the n type GaN layer 403, and it is SiO2. As a layer is shown in drawing 10 by reactive ion etching used for the mask, it is ****** to the n type GaN layer 403 of silicon addition of a part of wafer.
[0118] Next, as shown in drawing 11 , the electrode 408 of the alloy of n type Ti and aluminum and the electrode 409 of p type zinc and the alloy of Au were formed. It checked having realized the ohm nature contact with good n type and p type, without heat-treating especially.

[0119] As for the light emitting diode created as mentioned above, the GaN layer 403 of a substratum has the thickness of 4 micrometers. 405 is magnesium addition N layers of Ga1-x Alxes, x value is 0.15 and a thickness is 0.3 micrometers. Moreover, NMg in (4) formulas from the measurement result of the magnesium concentration by secondary ion mass analysis is 1.2x1019cm-3. Nbg1 It was background level (1.0x1016cm-3). That is, it is set to 4/(1600x0.15) =0.0167, and the occurrence conditions of the hole seen by the scanning electron microscope are d2. It is less than the value 0.3.
[0120] (4) the occurrence conditions of a formula to a crack -- NMg>Nbg1 it is -- since -- N -- 1.2x1019-1.0x1016= -- about 1.2x1019 -- it is -- 3.6x10-3x[log(1.2x1019)]/(0.15+0.02) +0.02=0.42 -- becoming -- d2 The value 0.3 has checked that it was lower than this.
[0121] Moreover, when the optical property was measured in this way, the peak of photogenesis wavelength is 420nm and was able to pass 20mA current on a low voltage called 3.6V. Moreover, luminous efficiency has realized 13.4% and very high luminous efficacy by the external quantum efficiency. When life test of this light emitting diode was performed with 40mA of currents, the percent defective after 1000 hour progress is 1% or less, and it was checked that reinforcement is achieved.
[0122] Thus, since according to the semiconductor light emitting device concerning the gestalt of operation of this invention the additive modality, the concentration, and the thickness in each class were adjusted so that the conditions of (4) formulas might be satisfied, in light emitting diode, remarkable reinforcement, elevation of the further luminous efficiency, and a reduction of operating voltage are realizable.
[0123] (Gestalt of the 2nd operation) (4) formulas by which the header was carried out [above-mentioned] with the gestalt of this operation -- and -- or blue laser diode was produced on the conditions with which (5) formulas are filled, and the element property was investigated Blue laser diode was produced using the organic-metal vapor-growth equipment shown in drawing 1 .
[0124] Drawing 12 , the drawing 13 , the drawing 14 , and the drawing 15 are process cross sections of the laser diode of the gestalt of operation of the 2nd of this invention.
[0125] In the vapor-growth equipment of drawing 1 , energization was started to the high-frequency-heating equipment 305, supplying hydrogen from a gas inlet 302, and the substrate 501 placed on the susceptor 304, i.e., the silicon on sapphire in drawing 12 , was heated, and it adjusted so that temperature might become 1200 degrees C. After holding in this status for 10 minutes, temperature was lowered to 600 degrees C, supply of TMG and ammonia gas was started in the stable place, and 40nm grew GaN buffer layer 502. Supply of TMG was stopped and temperature was re-raised at 1200 degrees C.
[0126] Subsequently, supply of the silane gas diluted with hydrogen and TMG was started, and 4 micrometers of the n type GaN layers 503 of silicon addition were grown up. Then, additional supply of the TMA was carried out and Ga0.85aluminum0.15N layer 504 [0.3-micrometer] of n type silicon addition was grown up. Next, it stopped to supply of TMA and silane gas, and 0.1 micrometers of the additive-free GaN layers 505 were grown up. Next, supply of TMG and a silane was stopped, temperature was lowered to 800 degrees C, after being stabilized, TMG

was supplied, and 4nm of barrier layers GaN was grown up. Well layer In0.15Ga0.85N [2nm] were grown up by adding TMI succeedingly. The multiplex quantum well (MQW) structure barrier layer 506 was created by repeating this barrier layer and a well layer and growing up 20 times. After stopping supply of TMI, temperature was returned to 1200 degrees C, additional supply of Cp2 Mg was carried out in the stable place, and 0.1 micrometers of p type GaNs507 were grown up.

[0127] Next, additional supply of the TMA was carried out and p mold Ga0.85aluminum0.15N layer 508 [0.3-micrometer] of magnesium addition was grown up. Then, supply of TMA was stopped and 1 micrometer of the p type GaN layers 509 of magnesium addition was grown up as it is.

[0128] Then, supply of TMG and Cp2 Mg was stopped and the energization to the high-frequency-heating equipment 305 was stopped. Supply of ammonia was stopped in the place where temperature fell to 850 degrees C. It was a mirror plane when the wafer picked out from the growth container 301 was inspected visually. Even if it observed by the differential interference microscope, the pattern of a characteristic surface state was not seen. That is, the crack was not seen all over the wafer. Moreover, although the surface state was observed by the scanning electron microscope, it is flat and characteristic patterns, such as a hole, a projection, and a wave, were not seen.

[0129] Next, etching conditions were determined on the basis of the distance from the maximum front face checked by cross-section electron microscope observation to the n type GaN layer 503. And SiO2 As a layer 510 is shown in drawing 13 by reactive ion etching used for the mask, it is ****** to the n type GaN layer 503 of silicon addition of a part of wafer.

[0130] Then, the fraction deleted by reactive ion etching immediately before using the polyimide 511 was buried, next the whole wafer was shaved, and the front face of p-GaN was exposed (drawing 14). It is SiO2 on it. It is ****** (drawing 15) to the n type GaN layer 503 of silicon addition of a part of wafer by reactive ion etching which used the layer 512 for the mask.

[0131] n type electrode of the alloy of Ti and aluminum is formed in this status, and it is SiO2. After removing the layer 512, p type electrode of the alloy of nickel and Au was formed. It checked having realized the ohm nature contact with good n type and p type, without heat-treating especially.

[0132] As for the laser diode created as mentioned above, the GaN layer 503 of a substratum has the thickness of 4 micrometers, 508 is magnesium addition N layers of Ga1-x Alxes, x is 0.15 and a thickness is 0.3 micrometers. Here, (4) formulas are applied by the relation between the GaN layer 503 of a substratum, and the Ga1-x AlxN layer 508. It is 1.2x1019cm-3 and the measurement result of the magnesium concentration by secondary ion mass analysis to NMg is Nbg1. It was background level (1.0x1016cm-3).

[0133] Therefore, it is set to 4/(1600x0.15) =0.0167, and the occurrence conditions of the hole of (4) formulas seen by the scanning electron microscope are d2. It is less than the value 0.3. moreover, NMg>Nbg1 it is -- since -- N -- 1.2x1019-1.0x1016= -- about 1.2x1019 -- it is -- the occurrence conditions of the crack of (4) formulas -- 3.6x10-3x[log(1.2x1019)]/(0.15+0.02)+0.02=0.42 -- becoming -- d2 The value 0.3 has checked that it was lower than this.

[0134] Moreover, the GaN layer 503 of a substratum has the thickness of 4 micrometers, 504 is silicon addition N layers of Ga1-x Alxes, x value is 0.15 and a thickness is 0.3 micrometers. Here, (5) formulas are applied by the relation of 504 the GaN layer 503 of a substratum, and N layers of Ga1-x Alxes. It is 3.6x1018cm-3 and the measurement result of the silicon concentration by secondary ion mass analysis to Nsi is Nbg2. It was background level (3.0x1017cm-3).

[0135] Therefore, it is set to 4/(1600x0.15) =0.0167, and the occurrence conditions of the hole of (5) formulas seen by the scanning electron microscope are d2. It is less than the value 0.3. moreover, Nsi>Nbg2 it is -- since -- N -- 3.6x1018-3.0x1017=3.3x1018 -- it is -- the occurrence conditions of the crack of (5) formulas -- 3.2x10-3x[log(3.3x1018)]/(0.15+0.02)+0.02=0.37 -- becoming -- d2 The value 0.3 has checked that it was lower than this.

[0136] Thus, about the produced blue laser diode, the property was measured at the room temperature. A 75mA current flowing under the voltage of 5.0V, and carrying out continuous oscillation of the concerned laser was checked.
[0137] Next, the examination was continuously continued in this status and the life until an oscillation stops was measured. Although the number of the elements which measured the life was 200 in total, the number of the elements which showed the life of 1000 hours was 132.
[0138] The number of the elements which carry out continuous oscillation on the other hand among the laser elements created on the silicon on sapphire of one sheet when the technique of this invention was not used was one. [many] Although continuous oscillation of this laser was carried out at the room temperature by the time 7V and 90mA of currents, the life was less than 1 hour. Thus, the thing with the blue laser diode more marked than the conventional thing produced with the gestalt of this operation currently progressed was checked.
[0139] Thus, since according to the semiconductor device concerning the gestalt of operation of this invention the additive modality, the concentration, and the thickness in each class were adjusted so that the conditions of (4) formulas and (5) formulas might be satisfied, a life can be raised by leaps and bounds not to mention a reduction of the operating voltage of the room temperature continuous oscillation of laser and a current value being achieved.
[0140] (Gestalt of the 3rd operation) (4) formulas by which the header was carried out [above-mentioned] with the gestalt of this operation — and — or blue laser diode of further others in the conditions with which (5) formulas are filled was produced, and the element property was investigated Blue laser diode was produced using the organic-metal vapor-growth equipment shown in drawing 1 .
[0141] Drawing 16 , the drawing 17 , the drawing 18 , and the drawing 19 are process cross sections of the laser diode of the gestalt of operation of the 2nd of this invention.
[0142] In drawing 16 , the process from GaN buffer layer 602 on silicon on sapphire 601 to p type GaN layer 609 growth is the same as that of the case where it is shown in the drawing 12 of the gestalt of the 3rd operation. After growing up the p type GaN layer 609, Cp2 Mg and silane gas were changed, and 0.2 micrometers of n type GaNs610 were grown up.
[0143] Then, supply of TMG and silane gas was stopped and the energization to the high-frequency-heating equipment 305 was stopped. Supply of ammonia was stopped in the place where temperature fell to 850 degrees C.
[0144] It was a mirror plane when the wafer picked out from the growth container 301 was inspected visually. Even if it observed by the differential interference microscope, the pattern of a characteristic surface state was not seen. That is, the crack was not seen all over the wafer. Moreover, although the surface state was observed by the scanning electron microscope, it is flat and characteristic patterns, such as a hole, a projection, and a wave, were not seen.
[0145] Next, etching conditions were determined on the basis of the distance from the maximum front face checked by cross-section electron microscope observation to the p type GaN layer 609. After that SiO2 It is ****** (drawing 17) to the p type GaN layer 609 of silicon addition of a part of wafer by reactive ion etching which used the layer for the mask.
[0146] Then, this wafer was again put in into the growth container 301, and temperature was raised to 1200 degrees C, passing ammonia gas. Supply of TMG and Cp2 Mg was started in the place which became 1200 degrees C, and 1 micrometer of p-GaNs611 was grown up (drawing 18). Then, supply of TMG and silane gas was stopped and the energization to the high-frequency-heating equipment 305 was stopped. Supply of ammonia was stopped in the place where temperature fell to 850 degrees C.
[0147] Next, SiO2 It is ****** (drawing 19) to the n type GaN layer 603 of silicon addition of a part of wafer by the ion etching for a reaction which used the layer 612 for the mask.
[0148] The electrode of the alloy of n type Ti and aluminum was formed in this status, and after removing SiO2 612, the electrode of the alloy of p type nickel and Au was formed. It checked having realized the ohm nature contact with good n type and p type, without heat-treating especially.
[0149] As for the laser diode created as mentioned above, the GaN layer 603 of a substratum

has the thickness of 4 micrometers, 608 is magnesium addition N layers of Ga1-x Alxes, x value is 0.15 and a thickness is 0.3 micrometers. Here, (4) formulas are applied by the relation of 608 the GaN layer 603 of a substratum, and N layers of Ga1-x Alxes. It is 1.2x1019cm-3 and NMg of the measurement result of the magnesium concentration by secondary ion mass analysis to (4) formulas is Nbg1. It was background level (1.0x1016cm-3).
[0150] Therefore, it is set to 4/(1600x0.15) =0.0167, and the occurrence conditions of the hole of (4) formulas seen by the scanning electron microscope are d2. It is less than the value 0.3. moreover, NMg>Nbg1 it is — since — N — 1.2x1019-1.0x1018 — it is — the occurrence conditions of the crack of (4) formulas — 3.6x10-3x[log(1.2x1019)]/(0.15+0.02)+0.02=0.42 — becoming — d2 The value 0.3 has checked that it was lower than this.
[0151] Moreover, the GaN layer 603 of a substratum has the thickness of 4 micrometers, 604 is silicon addition N layers of Ga1-x Alxes, x value is 0.15 and a thickness is 0.3 micrometers. Here, (5) formulas are applied by the relation of 604 the GaN layer 603 of a substratum, and N layers of Ga1-x Alxes. It is 3.6x1018cm-3 and Nsi of the measurement result of the silicon concentration by secondary ion mass analysis to (5) formulas is Nbg2. It was background level (3.0x1017cm-3).
[0152] Therefore, it is set to 4/(1600x0.15) =0.0167, and the occurrence conditions of the hole of (5) formulas seen by the scanning electron microscope are d2. It is less than the value 0.3. moreover, Nsi>Nbg2 it is — since — N — 3.6x1018-3.0x1017 — it is — the occurrence conditions of the crack of (5) formulas — 3.2x10-3x[log(3.3x1018)]/(0.15+0.02)+0.02= — about 0.37 — becoming — d2 The value 0.3 has checked that it was lower than this.
[0153] Thus, about the produced blue laser diode, property measurement and life measurement were performed like the case of the gestalt of the 2nd operation. Operating voltage is a value of 5.0V, and the result which does not almost have the laser element of the gestalt of the 2nd operation and inferiority was obtained.
[0154] Thus, since according to the semiconductor device concerning the gestalt of operation of this invention the additive modality, the concentration, and the thickness in each class were adjusted so that the conditions of (4) formulas and (5) formulas might be satisfied, the same effect as the case of the gestalt of the 2nd operation can be done so.
[0155] (Gestalt of the 4th operation) each of the gestalt of the 3rd operation from the above 1st — between the inside of the structure shown in view 9 , the drawing 12 , and the drawing 16 , the buffer layer 402 / 502/602, the n type GaN layer 403 / 503/603 — additive-free — the structure which sandwiched GaN was created Property investigation was conducted as described above about each of this semiconductor device.
[0156] Consequently, although influence was hardly looked at by the rough property, compared with the case where the concerned additive-free GaN layer of field status on the front face of the maximum of the laminated structure which carried out the growth end is not pinched, the degree of a mirror plane was intentionally good and flat nature was increasing.
[0157] thus — according to the semiconductor device concerning the gestalt of operation of this invention — the same configuration as the gestalt of the 3rd operation from the above 1st — additive-free — since GaN was inserted, the same effect as the gestalt of the 3rd operation is done so from the above 1st, and also the degree of the mirror plane of each element can be improved and flat nature can be raised
[0158] Therefore, it is desirable to pinch additive-free GaN layer when raising the property of a semiconductor device more.
[0159] With the gestalt of each 3rd operation, some examples were given as an n type p type ohm nature electrode material from the 1st described so far. However, the electrode configuration used for this invention is not restricted to these, and that what is necessary is just the electrode material and the heat treatment technique of showing the ohm nature the above-mentioned case and more than an EQC, it can deform variously and it can be carried out.
[0160] moreover, the gestalt of each 3rd operation from the 1st — setting — (4) formulas — and — or the case where the conditions of (5) formulas were applied to a light emitting device was explained However, this condition is applicable to all the semiconductor devices of the

gallium-nitride system as which occurrence prevention of a crack and a hole is requested. Therefore, it is applicable to the various elements in the domain which does not deviate from the meaning of this invention. For example, it is the the best also for the creation of a RF electric field effect element 1GHz [using the large band gap] or more, the super-high-speed electron-mobility transistor which uses two-dimensional element gas.

[0161] (Gestalt of the 5th operation) The gestalt of this operation adjusts an Si dope AlGaN clad layer and a Mg dope AlGaN clad layer thickness in the night ****** system semiconductor device constituted on substrates, such as a sapphire. Thereby, in the case of Mg dope, the effect that a crack is suppressed is used, without giving a problem to the ******** effect of laser.

[0162] Specifically, the thickness of a Mg dope layer AlGaN layer is made thicker than the thickness of n type or undoped type AlGaN layer. It devises adjusting so that optical asymmetry [in a clad layer for the light-guide layer thickness and composition which were established between the barrier layer and this clad layer] may be rectified etc. in that case.

[0163] Drawing 20 is drawing explaining the outline configuration of the blue semiconductor laser equipment concerning the gestalt of operation of the 5th of this invention.

[0164] Each nitride layers of all grew by MOCVD (organic-metal vapor growth).

[0165] In this blue semiconductor laser equipment on the sapphire substrate 101 GaN buffer layer 102 (0.03 micrometers of thicknesss) of low-temperature growth (550 degrees C) is formed. The n-GaN contact layer 103 (an Si dope) which grew at the elevated temperature (1100 degrees C) further on it The n lateral electrode 104, the n-aluminum0.15Ga0.85N clad layer 105 (the Si dope) which consist of 5x1018cm - 3 or 3 micrometers and nickel/Au The barrier-layer section 106 containing 5x1018cm - 3 or 0.25 micrometers, multiplex quantum well structure (MQW), and a light-guide layer is formed.

[0166] This barrier-layer section 106 has the light-guide layers 106a and 106b which consist of GaN with a thickness of 0.1 micrometers, as shown in drawing 21 in detail. Moreover, the well layer consists of the In0.18Ga0.82N3 layer of 3nm **, and a barrier layer consists of In0.04Ga0.96N [with a thickness of 5nm].

[0167] It sets to blue semiconductor laser equipment, and is the p-aluminum0.15Ga0.85N clad layer 107 (a Mg dope) on the barrier-layer section 106. 5x1019cm - 3 or 0.35 micrometers are prepared, and it is the cap layer for p-GaN re-growth 108 (a Mg dope) further. 5x1019cm - 3 or 0.3 micrometers, the p-GaN contact layer 109 (a Mg dope) 8x1019cm - 3 or 0.8 micrometers, the p+-GaN high concentration contact layer 110 (a Mg dope) 2x1020cm - 3 or 0.1 micrometers, the current constriction layer 111 (Si dope, 5x1018cm - 3 or 0.25 micrometers) which consists of n-In0.2 Ga0.8 N, and the p lateral electrode 112 are formed.

[0168] In addition, silicon on sapphire uses the c-th (0001) page, and the laser mirror is formed of the cleavage.

[0169] In AlGaN layer of high aluminum composition, it is very easy to produce a hexagonal-method-like crack that the conventional technique will describe. It does not result in an oscillation with the laser structure which does not take the cure to such a crack. Moreover, even if it compared and it resulted in the oscillation by few yields, the residual strain showed during energization the remarkable degradation considered to be the cause. The trapped-mode light which the instability of a trapped mode etc. actualized when making AlGaN clad layer thickness thin simply, in order to suppress a crack, and oozed out outside from clad will receive a loss in GaN contact layer etc., and laser of a low threshold cannot be realized.

[0170] On the other hand, as described above, the artificer etc. found out that it could grow up, without AlGaN layer which doped Mg generating a crack more thickly than n type AlGaN of undoping or Si dope. Thus, the conditions which neither the crack which the ground which can thicken 50% [20% to] thickness guessed AlGaN layer previously, and made each thickness and addition concentration the parameter, nor a hole generates are as having been shown in the above-mentioned (1) - (5) formula.

[0171] Laser equipment shown in drawing 20 is made into the structure which took in the crack prevention effect by this Mg positively, and fulfills the conditions of (4) formulas and (5) formulas.

[0172] Drawing 21 is drawing showing the band diagram by the side of the conduction band of the fraction of the n-AlGaN clad layer of the laser of the gestalt of this operation, the barrier-layer section, and a p-AlGaN clad layer.
[0173] The Si-AlGaN layer 105 which a crack tends to generate is made thin with 0.25 micrometers, and the Mg-AlGaN layer 107 which is a clad layer by the side of p is thickened with 0.35 micrometers. It combines and comes out, and it is total and this layer containing aluminum can be set below to the critical thickness of a crack. Moreover, although it becomes asymmetry to the trapped mode of light, the increase in a big threshold is not generated. Conversely, when the Mg-AlGaN layer 107 was also made thin with 0.25 micrometers, the threshold increased 50%.
[0174] Room temperature continuous oscillation of the laser produced in the gestalt of this operation was carried out with the threshold of 85mA. Oscillation wavelength was 415nm and operating voltage was 6V. In drawing 20 , the current constriction layer 111 uses n type InGaN, and has set it as composition which has a loss to photogenesis wavelength. That is, this structure is loss guide type transverse-mode control laser, and stripe width of face is set as 4 micrometers. InGaN layer is grown up in the domain of 700 to 900 degree C low temperature, it leaves masks, such as SiO2, on the cap layer for p-GaN re-growth 108, and the aperture is opened by carrying out the selective growth of the current constriction layer 111, when re-growing up. The p-GaN contact layer 109 is also SiO2. After removing a mask, it was growing up by re-growth and the p+-GaN high concentration contact layer 110 made concentration of Mg high especially for the contact.
[0175] Thus, without generating a crack, since according to the semiconductor laser equipment concerning the gestalt of operation of this invention the addition of magnesium Mg in each class etc. and the thickness of each class were adjusted so that it might become in a predetermined condition, it could use for the night ****** system semiconductor device, could be using AlGaN layer of high aluminum composition as the clad layer, and element resistance became low enough and not only a low threshold but its reliability improved sharply especially in semiconductor laser. Moreover, the manufacture technique is also easy and the usefulness is greatest.
[0176] (Gestalt of the 6th operation) The gestalt of this operation adjusts composition of an Si dope AlGaN clad layer and a Mg dope AlGaN clad layer in the night ****** system semiconductor device constituted on substrates, such as a sapphire. Thereby, in the case of Mg dope, the effect that a crack is suppressed is used, without giving a problem to the ******** effect of laser.
[0177] That is, aluminum composition of a Mg dope layer AlGaN layer is made higher than aluminum composition of n type or undoped type AlGaN layer. It devises adjusting so that optical asymmetry [in a clad layer for the light-guide layer thickness and composition which were established between the barrier layer and this clad layer] may be rectified etc. in that case.
[0178] Drawing 22 is drawing explaining the band diagram by the side of the conduction band of the fraction concerning the gestalt of operation of the 6th of this invention.
[0179] The structure shown in drawing 20 as laser structure is used. With the gestalt of this operation, aluminum composition of Si-AlGaN which a crack tends to generate is made low 10%. Thickness of the Si-AlGaN layer 105 which is a clad layer by the side of n was set to the same 0.35 micrometers as the thickness of the Mg-AlGaN layer 107 by the side of p. In addition, the conditions of (4) formulas and (5) formulas are fulfilled.
[0180] The crack is not generated in this combination. Moreover, although it becomes unsymmetrical to the trapped mode of light also in this case, the increase in a big threshold is not generated. Room temperature continuous oscillation of the laser produced in the gestalt of this operation was carried out with the threshold of 75mA. Oscillation wavelength was 415nm and operating voltage was 5.5V.
[0181] Thus, since according to the semiconductor laser equipment concerning the gestalt of operation of this invention the addition of magnesium Mg in each class etc. and the thickness of each class were adjusted so that it might become in a predetermined condition, the same

effect as the gestalt of the 5th operation can be done so.

[0182] (Gestalt cf the 7th operation) The gestalt of this operation adjusts an Si dope AlGaN clad layer and a Mg dope AlGaN clad layer thickness in the night ****** system semiconductor device constituted on substrates, such as a sapphire. Thereby, in the case of Mg dope, the effect that a crack is suppressed is used, without giving a problem to the ******** effect of laser.

[0183] That is, the thickness of a Mg dope layer AlGaN layer is made thicker than the thickness of n type or undoped type AlGaN layer. It devises adjusting so that optical asymmetry [in a clad layer for the light-guide layer thickness and composition which were established between the barrier layer and this clad layer] may be rectified etc. in that case.

[0184] Drawing 23 is drawing explaining the band diagram by the side of the conduction band of the fraction concerning the gestalt of operation of the 7th of this invention.

[0185] It is the same as that of the gestalt of the 5th operation to make thin the Si-AlGaN layer 105 which a crack tends to generate with 0.25 micrometers, and to thicken the Mg-AlGaN layer 107 which is a clad layer by the side of p with 0.35 micrometers.

[0186] The influence which becomes unsymmetrical to the trapped mode of light is reduced with devising a light-guide layer. That is, although 0.1-micrometer light-guide layer 106a is provided in n side of the barrier-layer section 106 as shown in drawing 23 , direct Mg-AlGaN is in contact with MQW p side. It is the design pulled back by n side guide layer 106a about a trapped-mode loss of the light in the n-GaN layer 103 occurring writing n side clad layer 105 thinly, and being pushed aside by the mode at p side.

[0187] Room temperature continuous oscillation of the laser produced in the gestalt of this operation was carried out with the threshold of 65mA. Oscillation wavelength was 415nm and operating voltage was 5V.

[0188] Thus, since according to the semiconductor laser equipment concerning the gestalt of operation of this invention the addition of magnesium Mg in each class etc. and the thickness of each class were adjusted so that it might become in a predetermined condition, the same effect as the gestalt of the 5th operation is done so, and also optical asymmetry is certainly cancelable by adjusting a light-guide layer thickness.

[0189] Moreover, although MQW was considered as the configuration which touches the Mg-AlGaN layer 107 directly with the gestalt of this operation, a light-guide layer may also be prepared in the meantime, and asymmetric correction may be carried out by adjusting each light-guide layer thickness of MQW both sides. Furthermore, composition of a light-guide layer may be adjusted and asymmetry may be rectified.

[0190] (Gestalt of operation of the octavus) The gestalt of this operation adjusts composition of an Si dope AlGaN clad layer and a Mg dope AlGaN clad layer in the night ****** system semiconductor device constituted on substrates, such as a sapphire. Thereby, in the case of Mg dope, the effect that a crack is suppressed is used, without giving a problem to the ******** effect of laser.

[0191] That is, a crack is prevented to n type AlGaN which is the conductivity type out of which a crack tends to come with doping simultaneously Mg of three or more [1x1019cm -] impurity concentration in addition to n type impurity. When optical asymmetry arises in a clad layer in that case, adjusting the light-guide layer thickness and composition which were established between the barrier layer and this clad layer etc. devises, and asymmetry is rectified.

[0192] Drawing 24 is drawing explaining the outline configuration of the blue semiconductor laser equipment concerning the gestalt of operation of the octavus of this invention.

[0193] Each nitride layers of all grew by MOCVD (organic-metal vapor growth).

[0194] In this blue semiconductor laser equipment on the sapphire substrate 203 GaN buffer layer 204 (0.03 micrometers) of low-temperature growth (550 degrees C) is formed. The n-GaN contact layer 205 (an Si dope) which grew at the elevated temperature (1100 degrees C) further on it The n lateral electrode 206, the n-aluminum0.15Ga0.85N clad layer 207 (Mg:5x1019cm-3 and Si:5x1018cm-3 simultaneous dope 0.35micrometer) which consist of 5x1018cm - 3 or 3 micrometers and Ti/Au, The barrier-layer section 208 containing multiplex

quantum well structure (MQW) and a light-guide layer is formed.
[0195] The barrier-layer section 208 has the light-guide layers 208a and 208b which consist of GaN with a thickness of 0.1 micrometers, as shown in drawing 25 in detail. Moreover, the well layer consists of the In0.18Ga0.82N3 layer of 3nm **, and a barrier layer consists of In0.04Ga0.96N [with a thickness of 5nm].
[0196] Blue semiconductor laser equipment is the p-aluminum0.15Ga0.85N clad layer 209 (a Mg dope) further. 5x1019cm - 3 or 0.35 micrometers, the cap layer for p-GaN re-growth 210 (a Mg dope) 5x1019cm - 3 or 0.3 micrometers, a p-GaN contact layer (a Mg dope) 8x1019cm-3, 0.8micrometer211, the p+-GaN high concentration contact layer 212 (a Mg dope) It has 2x1020cm - 3 or 0.1 micrometers, the p lateral electrode 213, and the embedding layer 214 (undoping, 0.25 micrometers) that consists of high resistance aluminum0.6 Ga0.4 N.
[0197] In addition, silicon on sapphire uses the c-th (0001) page, and the laser mirror is formed of the cleavage.
[0198] in drawing 24 , high resistance AlGaN is used for the embedding layer 214, and it is ****** in etching to a barrier layer -- it formed by the selective growth the back That is, this structure is an embedded type and the so-called BH structure, and stripe width of face is set as 3 micrometers. You may dope Zn etc., although AlGaN is formed into high resistance also by ********** when aluminum composition is high. Moreover, the Zn dope GaN may be used.
[0199] Drawing 25 is drawing explaining the band diagram by the side of the conduction band of the fraction concerning the gestalt of this operation.
[0200] With the gestalt of this operation, the simultaneous dope of Mg is carried out at the Si-AlGaN layer 207 which a crack tends to generate. Thickness was set to 0.35 micrometers as well as the Mg-AlGaN layer 209 which is a clad layer by the side of p. The crack is not generated in this combination. Mg is functioning as a crack control impurity with this structure. As described above, 5x1019cm-3 and Si are doped for Mg by the Si-AlGaN layer 207 5x1018cm-3. About 150 mevs and since the impurity level of Mg is deep, it is activated at a room temperature, and **** 207 serves as n type as a result compensated with p type and n type. The optical loss by doping Mg simultaneously and the influence which gives n carrier concentration are the parvus.
[0201] Room temperature continuous oscillation of the laser produced in the gestalt of this operation was carried out with the threshold of 75mA. Oscillation wavelength was 415nm and operating voltage was 5.5V.
[0202] Thus, since according to the semiconductor laser equipment concerning the gestalt of operation of this invention the addition of magnesium Mg in each class etc. and the thickness of each class were adjusted so that it might become in a predetermined condition, the same effect as the gestalt of the 5th operation can be done so.
[0203] (Gestalt of the 9th operation) the gestalt of each operation of the above 1st - the octavus -- (4) formulas -- and -- or it is made to prevent the crack initiation of AlGaN layer by making the conditions acquired by (5) formulas suit On the other hand, it is that the gestalt of this operation carries out total of the thickness of AlGaN layer more than the half of a full-epitaxial thickness, and the dominant lattice constant of a layer structure is made to become what is AlGaN layer, and prevents that a crack etc. occurs in AlGaN layer by the stacking fault accompanied by aluminum introduction. That is, it is the view of using a main layer as AlGaN layer.
[0204] Drawing 26 is a cross section showing the outline configuration of the blue semiconductor laser equipment which applied the compound semiconductor element containing the nitrogen concerning the gestalt of operation of the 9th of this invention.
[0205] Each nitride layers of all in this blue semiconductor laser equipment are grown up by MOCVD (organic-metal vapor growth).
[0206] First, on the sapphire substrate 11 shown in drawing 26 , GaN buffer layer 12 (0.03 micrometers) is grown up at low temperature (550 degrees C), and GaN single crystal buffer layer 13 (0.3 micrometers) is continuously grown up at an elevated temperature (1100 degrees C).
[0207] Furthermore, the n-aluminum0.15Ga0.85N contact layer 14 (Si dope, 1x1018cm - 3 or

1.5 micrometers) thick enough on it, The n-aluminum0.3 Ga0.3 N clad layer 15 (Si dope, 5x1017cm - 3 or 0.2 micrometers), A barrier layer 16, the p-aluminum0.3 Ga0.3 N clad layer 17 (Mg dope, 5x1017cm - 3 or 0.2 micrometers), and GaN contact layer 18 (Mg dope, one to 3x1018cm - 3 or 0.1 micrometers) are grown up one by one.

[0208] And the n lateral electrode 19 will be formed on the p lateral electrode 20 and the n-AlGaN contact layer 14 on GaN contact layer 18, and it will be constituted as blue semiconductor laser equipment. In addition, the barrier layer 16 has the structure where 100A In0.1 Ga0.9 N was inserted by both-sides aluminum0.1 Ga0.9 N (undoping).

The semiconductor device fraction of the blue semiconductor laser equipment shown in drawing 26 has the low-temperature growth GaN buffer layer 12, the elevated-temperature GaN single crystal buffer layer 13, and GaN contact layer 18 as a layer which mainly consists of GaN, and the sum thickness is about 0.43 micrometers. On the other hand, as a layer which mainly consists of AlGaN, there are the n-AlGaN contact layer 14, the n-AlGaN clad layer 15, the barrier layer 16, and a p-AlGaN clad layer 17, and the sum thickness is about 1.9 micrometers.

[0209] Thus, with the structure of this operation gestalt, to GaN layer, AlGaN layer is thick and the dominant lattice constant which constitutes a layer structure becomes the thing of AlGaN layer.

[0210] This mode is shown in the conceptual diagram of drawing 27 . In this case, it has become below the critical thickness that does not produce a crack etc., and although it is in the status that the compressive strain was introduced, as for each GaN layer, the trusion etc. can form and maintain a layer structure, without newly generating.

[0211] In addition, in not considering as the configuration in which AlGaN layer turns into the dominant layer of a layer structure as shown in the gestalt of such this operation, and not fulfilling the conditions of the above-mentioned (4) formula or (5) formulas, either, as shown in the conceptual diagram of drawing 28 , it will pull in AlGaN layer, asymmetry will arise, and a crack occurs.

[0212] By the way, when forming AlGaN layer using a sapphire substrate, as carried out also with the gestalt of this operation, it is required to insert the single crystal layer of GaN near a substrate, direct, or the substrate. This is because it is enabled to maintain the crystal growth after it by presence of this GaN layer even if there is asymmetry by the sapphire substrate or the low-temperature growth phase stated by the following, since GaN crystal has the tenacious property compared with the night ****** crystal containing aluminum. Therefore, generally it is made difficult to consider as the structure of continuing growing up good AlGaN layer completely through GaN layer from a sapphire substrate.

[0213] Thus, the elevated-temperature GaN single crystal buffer layer 13 is introduced in order to ease the grid injustice with the low-temperature growth GaN buffer layer 12 which is the sapphire substrate 11 or a ************ layer, and in order to attain such a purpose, it is a single crystal layer below a critical thickness.

[0214] Thus, the elevated-temperature GaN single crystal buffer layer 13 is carrying out the work which suppresses the trusion occurrence by the above-mentioned compressive strain after semiconductor device formation while it prevents the trusion propagation at the time of the crystal growth to the layer after the n-AlGaN contact layer 14. That is, if this elevated-temperature GaN single crystal buffer layer 13 does not exist, the trusion etc. will go into the low-temperature growth GaN buffer layer 12 which is a ************ layer by the compressive strain which originate in AlGaN layer after semiconductor device formation, and are generated. This trusion is spread upward, and although the trusion etc. is produced also in AlGaN layer which contains the light-emitting-device section after all, with this operation gestalt, trusion occurrence and propagation are prevented by the elevated-temperature GaN single crystal buffer layer 13.

[0215] In addition, since elevated-temperature GaN single crystal buffer layer 13 the very thing is below a critical thickness as described above, it does not newly produce the trusion, a crack, etc. from here.

[0216] Moreover, GaN buffer layer 12 of the shape of ************ which carried out low-

temperature growth as described above is formed in the interface with the sapphire substrate 11. In addition, ************ layers, such as AlN buffer layer which carried out low-temperature growth, are sufficient as this buffer layer 12. The ground such a buffer layer 12 is formed is that it works in the orientation eased by the trusion which exists about a stacking fault although a layer role dominant in nucleus-ized formation of a growth phase will be played, if a low-temperature growth buffer layer is ************-like. Therefore, the stacking fault with a sapphire substrate will be sharply eased by presence of such a low-temperature buffer layer, and a subsequent crystal growth will be continued good.

[0217] Therefore, growth of good GaN layer of single crystal nature is attained by presence of this low-temperature growth buffer layer, and, thereby, formation of the light-emitting-device section which consists of an AlGaN layer is attained.

[0218] When total of AlGaN layer is more than the half of a full-epitaxial thickness, the dominant lattice constant which constitutes a layer structure becomes the thing of AlGaN layer of a thick side, and a good crystallized state is maintained. In addition, although the thick film is [sake / ********] required for AlGaN layer to some extent, since GaN layer can make the total thickness thin if carriers concentration, such as a contact layer, etc. is rationalized, it can realize the above-mentioned structure.

[0219] Moreover, when measurement evaluation as a contact layer was carried out, the reduction effect of contact resistance that the compressive strain of GaN was considered to be the cause was seen. The effect which leads to the above improvements began to be acquired from the amount in which aluminum composition of AlGaN layer exceeds 10% as a compressive strain of GaN. Moreover, as a substrate, the case of oxide system substrates, such as a sapphire, was suitable for the lattice constant construction by such AlGaN layer.

[0220] The room temperature pulse oscillation of the blue semiconductor laser equipment constituted as mentioned above was carried out with the threshold of 105mA. Oscillation wavelength was 415nm and operating voltage was 10V.

[0221] Thus, in the compound semiconductor element containing the nitrogen concerning the gestalt of operation of the 9th of this invention, since AlGaN layer thickness in an epitaxial layer is carried out to more than a half and it was made to make the dominant lattice constant which constitutes a layer structure into the thing of AlGaN layer, it can use for a night ****** system semiconductor device, being able to obtain good AlGaN layer which does not generate a crack and being able to use AlGaN layer of high aluminum composition as a clad layer. The usefulness is greatest.

[0222] Therefore, it can make element resistance low enough and a low threshold is not only realizable, but it can raise a reliability sharply especially in semiconductor laser. The compound semiconductor element which contains by this the nitrogen of the outstanding property which can perform enough eye ******** to a barrier layer, eye carrier ******, etc. can be offered.

[0223] Moreover, it sets for the compound semiconductor element containing the nitrogen of the gestalt of this operation. Between the sapphire substrate 11 and the n-AlGaN contact layer 14, the low-temperature growth GaN buffer layer 12 and the elevated-temperature GaN single crystal buffer layer 13 below a critical thickness are formed. Since the fundamental grid mismatching of a substrate 11 and a night ****** system semiconductor growth phase is canceled and it was made to absorb the lattice constant difference by being that whose still dominant lattice constant is AlGaN layer Occurrence of new trusion, crack, etc. can be prevented, and the compound semiconductor element with few trusion and cracks can be obtained. Therefore, element resistance can be made low enough. By this single crystal GaN buffer layer 13 being formed, the flat nature on the front face of a crystal is also improved, and growth of good AlGaN layer is closed, if possible.

[0224] in addition, the case of the gestalt of this operation of AlGaN layer-thickness conditions — the same — carrying out — and (4) formulas — and — or you may manufacture the semiconductor light emitting device fitted to the conditions of (5) formulas If it does in this way, the crack initiation of AlGaN layer can be prevented much more to an authenticity, and a reliable gallium-nitride system semiconductor device can be obtained.

[0225] (Gestalt of the 10th operation) the gestalt of each operation of the above 1st – the octavus — (4) formulas — and — or it is made to prevent the crack initiation of AlGaN layer by making the conditions acquired by (5) formulas suit On the other hand, like the gestalt of the 9th operation, carry out total of the thickness of AlGaN layer more than the half of a full-epitaxial thickness, and the gestalt of this operation is made to become that whose dominant lattice constant of a layer structure is AlGaN layer, and prevents that a crack etc. occurs in AlGaN layer by the stacking fault accompanied by aluminum introduction. That is, it is the view of using a main layer as AlGaN layer.
[0226] Drawing 29 is a cross section showing the outline configuration of the blue semiconductor laser equipment which applied the compound semiconductor element containing the nitrogen concerning the gestalt of operation of the 10th of this invention.
[0227] Each nitride layers of all in this blue semiconductor laser equipment are grown up by MOCVD (organic-metal vapor growth).
[0228] On the sapphire substrate 21 shown in drawing 29 , first, AlGaN buffer layer 22 (0.03 micrometers) is grown up at low temperature (550 degrees C), and GaN single crystal buffer layer 40 (0.3 micrometers) is continuously grown up at an elevated temperature (1100 degrees C).
[0229] Furthermore, n-aluminum0.15Ga0.85N layer 23 [thick enough on it] (Si dope, 1x1018cm – 3 or 1.5 micrometers), n-GaN of 50A ** formed into the AlGaN layer 23 (an Si dope) The superlattice contact layer 24 which consists of the n-aluminum0.15Ga0.85N layer (Si dope, 5x1018cm-3) 50 pair of 8x1018cm-3 and 50A **, The n-aluminum0.3 Ga0.3 N clad layer 25 (Si dope, 5x1017cm – 3 or 0.2 micrometers), The barrier layer 26 of undoping used as the structure where 100A In0.1 Ga0.9 N was inserted by both-sides aluminum0.1 Ga0.9 N, The p-aluminum0.3 Ga0.3 N clad layer 27 (Mg dope, 5x1017cm – 3 or 0.2 micrometers) and GaN contact layer 28 (Mg dope, one to 3x1018cm – 3 or 0.1 micrometers) are grown up one by one. And the p lateral electrode 30 and the n lateral electrode 29 are formed, and it is constituted as blue semiconductor laser equipment.
[0230] In addition, GaN single crystal buffer layer 40 is formed for the same purpose as the case of GaN single crystal buffer layer 13 of the gestalt of the 9th operation. Moreover, although it does not thin-** especially here, AlGaN buffer layer 22 which carried out low-temperature growth is carrying out the same work as the low-temperature growth GaN buffer layer 12 explained with the gestalt of the 9th operation.
[0231] Room temperature continuous oscillation of the blue semiconductor laser equipment constituted as mentioned above was carried out with the threshold of 55mA. Oscillation wavelength was 415nm and operating voltage was 5V.
[0232] Thus, in the compound semiconductor element containing the nitrogen concerning the gestalt of operation of the 10th of this invention, since the contact layer of the superstructure which contains GaN as n-AlGaN besides the same configuration as the gestalt of the 9th operation was prepared, the same effect as the gestalt of the 9th operation is acquired, and also contact resistance elevation can be suppressed and much more low resistance-ization can be attained.
[0233] That is, the height of a barrier becomes low by alloy-ization after electrode 29 formation, and the false two-dimensional electron gas in a superlattice can convey the poured-in current to low resistance to barrier-layer-izing.
[0234] moreover, the case of the gestalt of this operation of AlGaN layer-thickness conditions — the same — carrying out — and (4) formulas — and — or you may manufacture the semiconductor light emitting device fitted to the conditions of (5) formulas If it does in this way, the crack initiation of AlGaN layer can be prevented much more to an authenticity, and a reliable gallium-nitride system semiconductor device can be obtained.
[0235] In addition, in the gestalt of the above 1st – the 10th implementation, although explained by the case where a sapphire is used as a substrate, it is not limited to this and a substrate applicable to this invention can use various substrates, such as barium oxide BaO, zinc oxide ZnO, silicon carbide SiC, and a spinel machine.
[0236] Moreover, in the gestalt of the above 1st – the 10th implementation, as a

semiconductor layer to use, SiC etc. can be applied instead of GaN single crystal buffer layer, and an II-VI group compound semiconductor, Si, germanium, etc. may be used. furthermore, the amount about [which does not become mixed crystal about elements, such as In, Ti, Si, C, and nickel, at this although the object layer which demonstrates the function as a semiconductor device here was explained by the case of AlGaN] an impurity — you may contain The semiconductor device obtained by this invention is applicable also to various electron device fields, such as transistors, such as a photo detector which used the compound semiconductor or a heterojunction bipolar transistor (HBT), and a high mobility transistor (HEMT), as well as the ability to be adapted for the structural almost same light emitting diode besides laser.

[0237] in addition, in the domain which is not limited to the gestalt of each above-mentioned implementation, and does not deviate from the summary, many things are boiled and this invention can be deformed

[0238]

[Effect of the Invention] As a full account was given above, occurrence of a crack can be prevented, without according to this invention, avoiding the stacking-fault problem accompanied by aluminum introduction, and **ing thickness of Ga1-x Alx N, and aluminum composition of AlGaN layer can be made high, for example, the gallium-nitride system semiconductor device and gallium-nitride system semiconductor photogenesis equipment sufficient [eye ******** or eye carrier ******] to a barrier layer which may be carried out can be offered.

[Translation done.]